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THE OPEN OCEAN OPERATIONAL ENVIRONMENT

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The objective of this paper is to define a standard operational environment for the open ocean and air space above that will be used as a basis for the comparative analyses that form a principle part of the ANVCE program. While every effort has been made to develop environmental definitions that are reasonably representative, it is the comparative basis that is the key issue, and definitions have been chosen so that they will relate in a simple manner to performance and operability information likely to be

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TABLE OF CONTENTS

A

1. INTRODUCTION

The objective of this paper is to define a standard operational environment for the open ocean and air space above that will be used as a basis for the comparative analyses that form a principle part of the ANVCE program. While every effort has been made to develop environmental definitions that are reasonably representative, it is the comparative basis that is the key issue, and definitions have been chosen so that they will relate in a simple manner to performance and operability information likely to be available to the investigating teams. It is intended that this standard environment be used for all studies concerned with open ocean operation.

2. THE ENVIRONMENT

For the purpose of this program the operational environment is defined in terms of the following parameters:

- sea state - defined by wave characteristics
- wind speed - defined by speed, direction and altitude
- air temperature, pressure, density and viscosity
- water temperature, density and viscosity.

Of the parameters listed above, sea state and wind speed occur with wide variations in intensity. Since these parameters are also likely to be the most influential in determining vehicle performance their probability of occurrence is also defined herein.

2.1 Sea State

The North Atlantic is chosen as the design operational area; a choice which is considered to be both reasonable and conservative. Data from the various weather ship stations in the North Atlantic such as that contained in Reference 1, have been combined to provide a set of average or representative conditions. These data have been used as the basis for the sea state description which follows.

In order to provide a common basis for comparison it will be assumed that each sea state will be represented by a single wave spectrum and that the total probability of occurrence of each sea state will be as defined in Table 1.

Whenever necessary, vehicle performance will be quoted for the combination of standard sea states and wind speeds given in Table 1. For all calculations it will be assumed that the principal direction of sea state propagation and surface wind directions are the same.

It has been decided that the Pierson-Moskowitz family of wave spectra will be adopted to define each sea state although it is well known that this representation is not well suited to simulating swell conditions or very high sea states. The Pierson-Moskowitz spectra, however, are in general use; most model test tanks are set up to generate waves in this form and a great deal of information is available about the behavior of various vehicles in model scale waves generated in this way. For similar reasons a two-dimensional (long-crested) representation of ocean waves will be specified as this will more readily facilitate the use of model test results and less complex analytical representations.

The Pierson-Moskowitz (single parameter) spectrum is defined as follows:

$$S(\omega) = (8.1 \times 10^{-3}) g^2 \omega^{-5} e^{-.74\left(\frac{\omega_o}{\omega}\right)^4}, \frac{ft^2}{Rad/sec} \tag{1}$$

Table 1. Simplified Sea State Definitions

Sea State	Significant Wave Height, $H_{1/3}$ ft	m	Percentage Occurrence* (%)	Associated Wind Speed in Knots †
0	0.0	0.0	0	0
1	0.60	0.18	5.0	2
2	2.2	0.67	13.5	6
3	4.6	1.40	26.0	10
4	6.9	2.10	27.0	16
5	10.0	3.05	20.0	26
6	15.0	4.57	7.0	38
7	30.0	9.14	1.97	53
8	50.0	15.24	0.03	67

* Percentage of total time at sea.

† Wind speed at an elevation 30 ft (9.14 m) above mean sea surface. See Figure 2 for conversion to elevations other than 30 ft.

Where

$$\omega_o = \sqrt{0.21g/H_{1/3}} \text{ , radians/second}$$

ω = $2\pi f$ = circular frequency, rad/sec

f = wave encounter frequency as seen by a stationary observer

$H_{1/3}$ = The significant wave height, ft

Note that the typical solutions to equation (1), presented in Figure 1, are in terms of cyclic frequency (f), cycles per second, as opposed to circular frequency (ω) radians/second (i.e. S(f) is shown as a function of (f).

It is intended that all new performance and seakeeping information requested to support the ANVCE program, be for operation in sea states as defined by equation (1). For example, the seas to be modeled in any new tow tank tests shall be as close as is practical to the appropriate scaled equivalent seas defined by equation (1). Similarly all future analytical studies will use, when required, the sea states defined by equation (1). This will apply to all frequency domain studies which use the classical techniques originally defined in Reference 2. It will also apply to time domain studies for which time histories of waves used will contain wave heights and frequencies having the spectral distribution of equation (1). Where sea state descriptions are used that do not conform with this standard, it shall so be stated. For performance and seakeeping information that will be available only in terms of operation in regular seas then the crest to trough regular wave height to be used for sea state will be a factor of 0.68 times the corresponding 1/3 significant height given in Table 1.

2.2 Wind Definition

Standard wind speeds and their probability of occurrence will be selected from those defined in Table 1. The probability data for winds of varying strength given in Table 1 are for winds that are assumed to exist at an elevation of 30 ft (9.14 m) above the mean sea surface. Wind speeds, on a given day, will however vary considerably with altitude. For studies concerned with near surface operation (less than 100 ft or 30 m above the mean sea surface) a factor derived from the wind gradient curve of Figure 2 will apply to the wind speeds (of given probability) presented in Table 1.

2.3 Atmospheric Standard

All performance data will be quoted for conditions defined by the International Standard Atmosphere (ISA) as shown in Table 2.

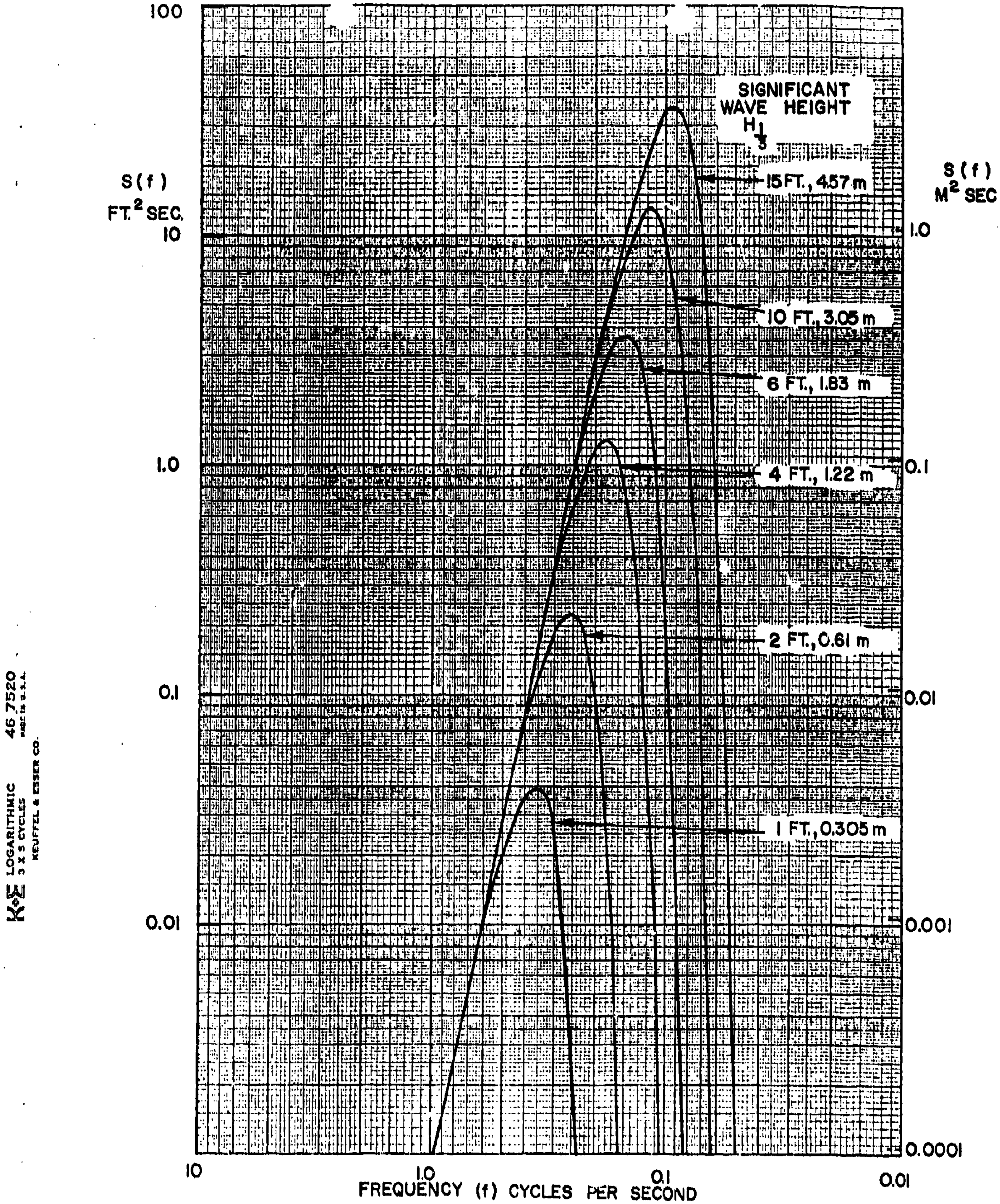
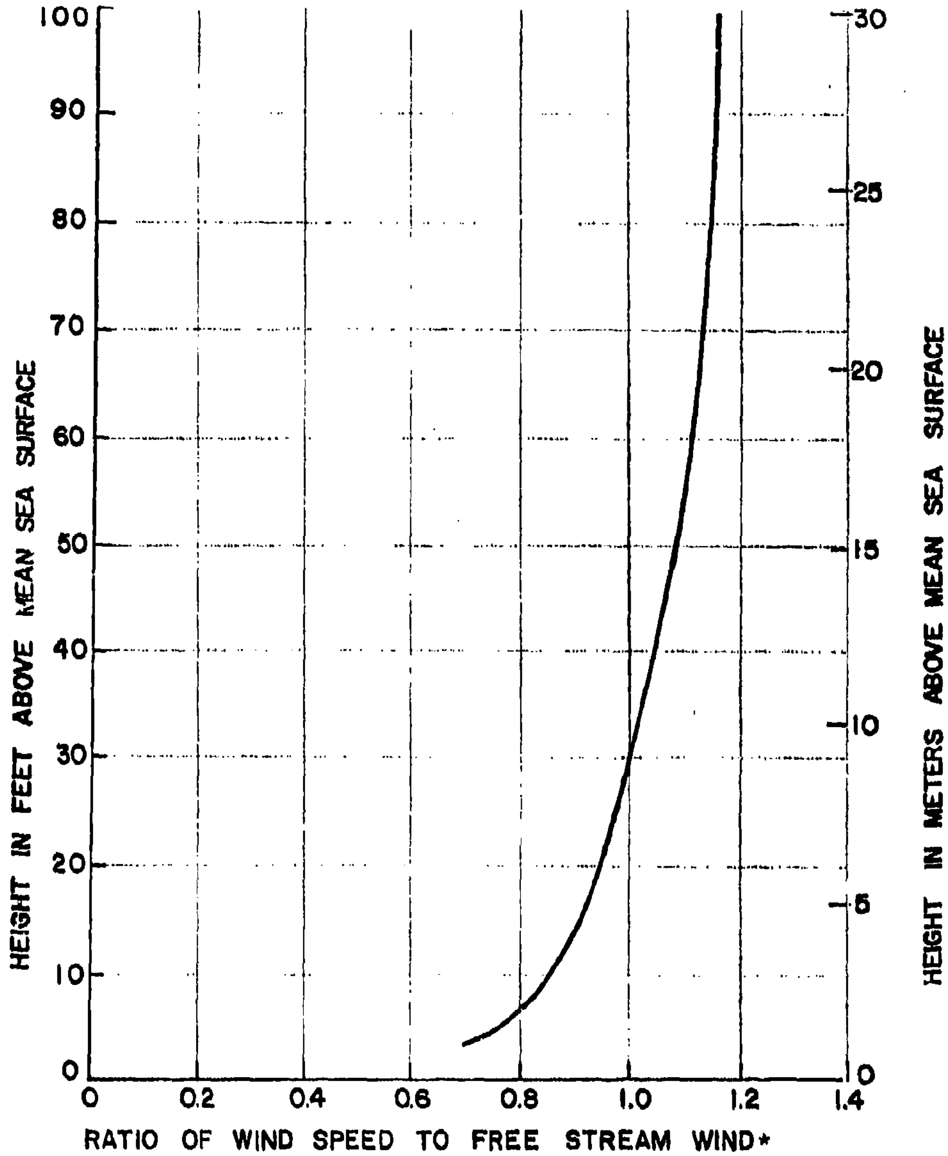


Figure 1. Pierson-Moskowitz Sea Spectrum.



* Free stream at 30 ft (9.144 m) above mean sea surface

Figure 2. Wind Gradient Above Sea Surface.

Table 2. Standard Atmosphere.

Altitude Above Sea Level		Temperature		Pressure		Density		Kinematic Viscosity	
Ft	m	°F	°C	(lb/ft^2) abs	N/m^2	$Slugs/Ft^3$	Kg/m^3	$1\times10^{-4}\ Ft^2/sec$	$1\times10^{-5} m^2/sec$
0	0	59	15	2116.2	101.32	0.002378	1.226	1.564	1.453
1000	305	55.44	13.02	2040.9	97.719	0.002310	1.191	1.602	1.488
2000	610	51.87	11.04	1967.7	94.214	0.002242	1.155	1.641	1.524
3000	914	48.31	9.06	1896.7	90.814	0.002177	1.122	1.681	1.562
4000	1219	44.74	7.08	1827.7	87.510	0.002112	1.088	1.723	1.601
5000	1524	41.18	5.10	1760.8	84.307	0.002049	1.056	1.766	1.641
10000	3048	23.36	-4.80	1455.4	69.685	0.001756	0.905	2.002	1.860
15000	4572	5.54	-14.70	1194.3	57.183	0.001497	0.7715	2.280	2.118
20000	6096	-12.28	-24.60	972.6	46.568	0.001267	0.6322	2.608	2.423
25000	7620	-30.10	-34.50	785.3	37.600	0.001066	0.549	2.999	2.786

2.4 Standard Water

Wherever applicable performance will be quoted for the standard water conditions specified in Table 3.

Table 3. Standard Water (Salt Water).

Property	British Units	Metric Units
Temperature	59° F	15°C
Weight density w	64.04 lb/ft^3	1028 kg/m^3
Kinematic Viscosity (μ/ρ)	1.282×10^{-5} ft^2/sec	0.119×10^{-5} m^2/sec

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